

PCTWORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : C07K 1/00, 14/00, 17/00, C07H 21/02, 21/04, G01N 33/53	A1	(11) International Publication Number: WO 98/37085 (43) International Publication Date: 27 August 1998 (27.08.98)
(21) International Application Number: PCT/US98/03143 (22) International Filing Date: 19 February 1998 (19.02.98) (30) Priority Data: 08/808,982 19 February 1997 (19.02.97) US (71) Applicant: THE REGENTS OF THE UNIVERSITY OF CALIFORNIA [US/US]; 22nd floor, 300 Lakeside Drive, Oakland, CA 94612-3550 (US). (72) Inventors: TESSIER-LAVIGNE, Marc; University of California, San Francisco, Dept. Anatomy S-1479, San Francisco, CA 94143 (US). LEONARDO, E., David; University of California, San Francisco, Dept. Anatomy S-1479, San Francisco, CA 94143 (US). HINCK, Lindsay; University of California, San Francisco, Dept. Anatomy S-1479, San Francisco, CA 94143 (US). MASU, Masayuki; University of California, San Francisco, Dept. Anatomy S-1479, San Francisco, CA 94143 (US). KEINO-MASU, Kazuko; University of California, San Francisco, Dept. Anatomy S-1479, San Francisco, CA 94143 (US). (74) Agent: OSMAN, Richard, Aron; Science & Technology Law Group, 75 Denise Drive, Hillsborough, CA 94010 (US).		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i>
(54) Title: NETRIN RECEPTORS (57) Abstract The invention provides methods and compositions relating to vertebrate UNC-5 proteins which function as receptor proteins for netrins, a family of cell guidance proteins. The proteins may be produced recombinantly from transformed host cells from the disclosed vertebrate UNC-5 encoding nucleic acid or purified from human cells. The invention provides specific hybridization probes and primers capable of specifically hybridizing with the disclosed vertebrate <i>unc-5</i> gene, vertebrate UNC-5-specific binding agents such as specific antibodies, and methods of making and using the subject compositions in diagnosis, therapy and in the biopharmaceutical industry.		

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav	TM	Turkmenistan
BF	Burkina Faso	GR	Greece		Republic of Macedonia	TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's	NZ	New Zealand		
CM	Cameroon		Republic of Korea	PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakhstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

Netrin Receptors

Inventors: Marc Tessier-Lavigne, E. David Leonardo, Lindsay Hinck, Masayuki Masu,
Kazuko Keino-Masu

5 The research carried out in the subject application was supported in part by grants
from the National Institutes of Health. The government may have rights in any patent issuing
on this application.

INTRODUCTION

Field of the Invention

10 The field of this invention is proteins which regulate vertebrate cell guidance.

Background

15 In the developing nervous system, migrating cells and axons are guided to their targets
by cues in the extracellular environment. The netrins are a family of phylogenetically-
conserved guidance cues that can function as diffusible attractants and repellents for different
classes of cells and axons¹⁻¹⁰. Recent studies in vertebrates, insects and nematodes have
implicated members of the DCC subfamily of the immunoglobulin (Ig) superfamily as
receptors involved in migrations toward netrin sources^{6, 11-13}. The mechanisms that direct
migrations away from netrin sources (presumed repulsions) are less well understood. In
Caenorhabditis elegans, loss of *unc-5* (which encodes the transmembrane protein UNC-5¹⁴)
20 function causes defects in these migrations^{15, 16}, and ectopic expression of *unc-5* in some
neurons can redirect their axons away from a netrin source¹⁷. However, the relationship
between UNC-5 and the netrins has not been defined. We disclose herein vertebrate
homologues of the *C. elegans* UNC-5, which define a novel subfamily of the Ig superfamily,
and whose mRNAs show prominent expression in various classes of differentiating neurons
25 and we disclose that these vertebrate UNC-5 homologues are vertebrate netrin-binding
proteins.

SUMMARY OF THE INVENTION

30 The invention provides methods and compositions relating to vertebrate UNC-5
proteins, related nucleic acids, and protein domains thereof having vertebrate UNC-5-specific
activity. The proteins may be produced recombinantly from transfected host cells from the

subject vertebrate UNC-5 encoding nucleic acids or purified from vertebrate cells. The invention provides isolated vertebrate *unc-5* hybridization probes and primers capable of specifically hybridizing with the disclosed vertebrate *unc-5* genes, vertebrate UNC-5-specific binding agents such as specific antibodies, and methods of making and using the subject compositions in diagnosis (e.g. genetic hybridization screens for vertebrate *unc-5* transcripts), therapy (e.g. gene therapy to modulate vertebrate *unc-5* gene expression) and in the biopharmaceutical industry (e.g. as immunogens, reagents for modulating cell guidance, reagents for screening chemical libraries for lead pharmacological agents, etc.).

DETAILED DESCRIPTION OF THE INVENTION

The nucleotide sequences of natural *unc5h-1* cDNAs from rat and human are shown as SEQ ID NOS:1 and 2, respectively; and the conceptual translates are shown as SEQ ID NOS: 5 and 6, respectively. The nucleotide sequences of natural *unc5h-2* cDNAs from rat and human are shown as SEQ ID NOS:3 and 4, respectively; and the conceptual translates are shown as SEQ ID NOS:7 and 8, respectively. The vertebrate UNC-5 proteins of the invention include incomplete translates of SEQ ID NOS:1, 2, 3 and 4 and deletion mutants of SEQ ID NOS:5, 6, 7 and 8, which translates and deletion mutants have vertebrate UNC-5-specific amino acid sequence and assay-discernable vertebrate UNC-5-specific binding specificity or function. Such active vertebrate UNC-5 deletion mutants, vertebrate UNC-5 peptides or protein domains comprise at least about 8, preferably at least about 12, more preferably at least about 24 consecutive residues of SEQ ID NO:5, 6, 7 or 8. For examples, vertebrate UNC-5 protein domains identified below are shown to provide protein-binding domains which are identified in and find use, *inter alia*, in solid-phase binding assays as described below.

Vertebrate UNC-5-specific activity or function may be determined by convenient *in vitro*, cell-based, or *in vivo* assays: e.g. *in vitro* binding assays, cell culture assays, in animals (e.g. gene therapy, transgenics, etc.), etc. Binding assays encompass any assay where the molecular interaction of a vertebrate UNC-5 protein with a binding target is evaluated. The binding target may be a natural extracellular binding target such as a netrin protein, or other regulator that directly modulates vertebrate UNC-5 activity or its localization; or non-natural binding target such a specific immune protein such as an antibody, or an vertebrate UNC-5 specific agent such as those identified in screening assays such as described below.

Vertebrate UNC-5-binding specificity may assayed by binding equilibrium constants (usually at least about 10^7 M^{-1} , preferably at least about 10^8 M^{-1} , more preferably at least about 10^9 M^{-1}), by the ability of the subject protein to function as negative mutants in vertebrate UNC-5-expressing cells, to elicit vertebrate UNC-5 specific antibody in a heterologous mammalian host (e.g a rodent or rabbit), etc. In any event, the vertebrate UNC-5 binding specificity of the subject vertebrate UNC-5 proteins necessarily distinguishes *C. elegans* UNC-5.

The claimed vertebrate UNC-5 proteins are isolated or pure: an "isolated" protein is unaccompanied by at least some of the material with which it is associated in its natural state, preferably constituting at least about 0.5%, and more preferably at least about 5% by weight of the total protein in a given sample and a pure protein constitutes at least about 90%, and preferably at least about 99% by weight of the total protein in a given sample. The vertebrate UNC-5 proteins and protein domains may be synthesized, produced by recombinant technology, or purified from mammalian, preferably human cells. A wide variety of molecular and biochemical methods are available for biochemical synthesis, molecular expression and purification of the subject compositions, see e.g. Molecular Cloning, A Laboratory Manual (Sambrook, *et al.* Cold Spring Harbor Laboratory), Current Protocols in Molecular Biology (Eds. Ausubel, *et al.*, Greene Publ. Assoc., Wiley-Interscience, NY) or that are otherwise known in the art.

The invention provides natural and non-natural vertebrate UNC-5-specific binding agents, methods of identifying and making such agents, and their use in diagnosis, therapy and pharmaceutical development. For example, vertebrate UNC-5-specific agents are useful in a variety of diagnostic and therapeutic applications. Vertebrate UNC-5-specific binding agents include vertebrate UNC-5-specific ligands, such as netrins, and somatically recombined protein receptors like specific antibodies or T-cell antigen receptors (see, e.g. Harlow and Lane (1988) Antibodies, A Laboratory Manual, Cold Spring Harbor Laboratory) and other natural binding agents identified with assays such as one-, two- and three-hybrid screens, non-natural binding agents identified in screens of chemical libraries such as described below, etc. For diagnostic uses, the binding agents are frequently labeled, such as with fluorescent, radioactive, chemiluminescent, or other easily detectable molecules, either conjugated directly to the binding agent or conjugated to a probe specific for the binding agent. Agents of particular interest modulate vertebrate UNC-5 function, e.g. vertebrate UNC-5-dependent cell guidance; for example, isolated cells, whole tissues, or individuals

may be treated with a vertebrate UNC-5 binding agent to activate, inhibit, or alter vertebrate UNC-5-dependent cell guidance or function.

The invention provides UNC-5 related nucleic acids, which find a wide variety of applications including use as translatable transcripts, hybridization probes, PCR primers, diagnostic nucleic acids, etc.; use in detecting the presence of *unc-5* genes and gene
5 transcripts and in detecting or amplifying nucleic acids encoding additional *unc-5* homologs and UNC-5 structural analogs. The subject nucleic acids are of synthetic/non-natural sequences and/or are isolated, i.e. unaccompanied by at least some of the material with which it is associated in its natural state, preferably constituting at least about 0.5%, preferably at least about 5% by weight of total nucleic acid present in a given fraction, and usually
10 recombinant, meaning they comprise a non-natural sequence or a natural sequence joined to nucleotide(s) other than that which it is joined to on a natural chromosome. Nucleic acids comprising the nucleotide sequence of SEQ ID NO:1, 2, 3 or 4 or fragments thereof, contain such sequence or fragment at a terminus, immediately flanked by a sequence other than that which it is joined to on a natural chromosome, or flanked by a native flanking region fewer
15 than 10 kb, preferably fewer than 2 kb, which is at a terminus or is immediately flanked by a sequence other than that which it is joined to on a natural chromosome. While the nucleic acids are usually RNA or DNA, it is often advantageous to use nucleic acids comprising other bases or nucleotide analogs to provide modified stability, etc.

The amino acid sequences of the disclosed vertebrate UNC-5 proteins are used to
20 back-translate vertebrate UNC-5 protein-encoding nucleic acids optimized for selected expression systems (Holler et al. (1993) Gene 136, 323-328; Martin et al. (1995) Gene 154, 150-166) or used to generate degenerate oligonucleotide primers and probes for use in the isolation of natural vertebrate UNC-5-encoding nucleic acid sequences ("GCG" software, Genetics Computer Group, Inc, Madison WI). vertebrate UNC-5-encoding nucleic acids used
25 in vertebrate UNC-5-expression vectors and incorporated into recombinant host cells, e.g. for expression and screening, transgenic animals, e.g. for functional studies such as the efficacy of candidate drugs for disease associated with vertebrate UNC-5-modulated transcription, etc.

The invention also provides nucleic acid hybridization probes and replication / amplification primers having a vertebrate UNC-5 cDNA specific sequence contained in SEQ
30 ID NO:1, 2, 3 or 4 and sufficient to effect specific hybridization thereto (i.e. specifically hybridize with the corresponding SEQ ID NO:1, 2, 3 or 4 in the presence of *C. elegans unc-5*

cDNA). Such primers or probes are at least 12, preferably at least 24, more preferably at least 36 and most preferably at least 96 bases in length. Demonstrating specific hybridization generally requires stringent conditions, for example, hybridizing in a buffer comprising 30% formamide in 5 x SSPE (0.18 M NaCl, 0.01 M NaPO₄, pH7.7, 0.001 M EDTA) buffer at a temperature of 42°C and remaining bound when subject to washing at 42°C with 0.2 x SSPE; preferably hybridizing in a buffer comprising 50% formamide in 5 x SSPE buffer at a temperature of 42°C and remaining bound when subject to washing at 42°C with 0.2 x SSPE buffer at 42°C. vertebrate UNC-5 cDNA homologs can also be distinguished from other protein using alignment algorithms, such as BLASTX (Altschul *et al.* (1990) Basic Local Alignment Search Tool, J Mol Biol 215, 403-410).

Vertebrate *unc-5* hybridization probes find use in identifying wild-type and mutant vertebrate *unc-5* alleles in clinical and laboratory samples. Mutant alleles are used to generate allele-specific oligonucleotide (ASO) probes for high-throughput clinical diagnoses. Therapeutic vertebrate UNC-5 nucleic acids are used to modulate cellular expression or intracellular concentration or availability of active vertebrate UNC-5. For example, vertebrate UNC-5 nucleic acids are also used to modulate cellular expression or intracellular concentration or availability of active vertebrate UNC-5 protein. Vertebrate UNC-5 inhibitory nucleic acids are typically antisense: single-stranded sequences comprising complements of the disclosed natural vertebrate UNC-5 coding sequences. Antisense modulation of the expression of a given vertebrate UNC-5 protein may employ antisense nucleic acids operably linked to gene regulatory sequences. Cells are transfected with a vector comprising a vertebrate UNC-5 sequence with a promoter sequence oriented such that transcription of the gene yields an antisense transcript capable of binding to endogenous vertebrate UNC-5 encoding mRNA. Transcription of the antisense nucleic acid may be constitutive or inducible and the vector may provide for stable extrachromosomal maintenance or integration. Alternatively, single-stranded antisense nucleic acids that bind to genomic DNA or mRNA encoding a given vertebrate UNC-5 protein may be administered to the target cell, in or temporarily isolated from a host, at a concentration that results in a substantial reduction in expression of the targeted protein. An enhancement in vertebrate UNC-5 expression is effected by introducing into the targeted cell type vertebrate UNC-5 nucleic acids which increase the functional expression of the corresponding gene products. Such nucleic acids may be vertebrate UNC-5 expression vectors, vectors which upregulate

the functional expression of an endogenous allele, or replacement vectors for targeted correction of mutant alleles. Techniques for introducing the nucleic acids into viable cells are known in the art and include retroviral-based transfection, viral coat protein-liposome mediated transfection, etc.

The invention provides efficient methods of identifying agents, compounds or lead compounds for agents active at the level of a vertebrate UNC-5 modulatable cellular function. Generally, these screening methods involve assaying for compounds which modulate vertebrate UNC-5 interaction with a natural vertebrate UNC-5 binding target. A wide variety of assays for binding agents are provided including labeled *in vitro* protein-protein binding assays, immunoassays, cell based assays, animal based assay, etc. Preferred methods are amenable to automated, cost-effective high throughput screening of chemical libraries for lead compounds. Such libraries encompass candidate agents of numerous chemical classes, though typically they are organic compounds; preferably small organic compounds and are obtained from a wide variety of sources including libraries of synthetic or natural compounds. Identified agents find use in the pharmaceutical industries for animal and human trials; for example, the agents may be derivatized and rescreened in *in vitro* and *in vivo* assays to optimize activity and minimize toxicity for pharmaceutical development.

In vitro binding assays employ a mixture of components including vertebrate UNC-5 protein, which may be part of a fusion product with another peptide or polypeptide, e.g. a tag for detection or anchoring, etc. The assay mixtures comprise a natural extracellular vertebrate UNC-5 binding target, such as a netrin. While native binding targets may be used, it is frequently preferred to use portions (e.g. peptides) thereof so long as the portion provides binding affinity and avidity to the subject vertebrate UNC-5 protein conveniently measurable in the assay. The assay mixture also comprises a candidate pharmacological agent and typically, a variety of other reagents such as salts, buffers, neutral proteins, e.g. albumin, detergents, protease inhibitors, nuclease inhibitors, antimicrobial agents, etc. The mixture components can be added in any order that provides for the requisite bindings and incubations may be performed at any temperature which facilitates optimal binding. The mixture is then incubated under conditions whereby, but for the presence of the candidate pharmacological agent, the vertebrate UNC-5 protein specifically binds the cellular binding target, portion or analog with a reference binding affinity. Incubation periods are likewise selected for optimal binding but also minimized to facilitate rapid, high-throughput screening.

After incubation, the agent-biased binding between the vertebrate UNC-5 protein and one or more binding targets is detected. A separation step is often initially used to separate bound from unbound components. Separation may be effected by precipitation (e.g. TCA precipitation, immunoprecipitation, etc.), immobilization (e.g. on a solid substrate), etc., followed by washing by, for examples, membrane filtration, gel chromatography (e.g. gel filtration, affinity, etc.). One of the components usually comprises or is coupled to a label. The label may provide for direct detection such as radioactivity, luminescence, optical or electron density, etc. or indirect detection such as an epitope tag, an enzyme, etc. A variety of methods may be used to detect the label depending on the nature of the label and other assay components, e.g. through optical or electron density, radiative emissions, nonradiative energy transfers, etc. or indirectly detected with antibody conjugates, etc. A difference in the binding affinity of the vertebrate UNC-5 protein to the target in the absence of the agent as compared with the binding affinity in the presence of the agent indicates that the agent modulates the binding of the vertebrate UNC-5 protein to the vertebrate UNC-5 binding target. Analogously, in the cell-based transcription assay also described below, a difference in the vertebrate UNC-5 transcriptional induction in the presence and absence of an agent indicates the agent modulates vertebrate UNC-5-induced transcription. A difference, as used herein, is statistically significant and preferably represents at least a 50%, more preferably at least a 90% difference.

The following experimental section and examples are offered by way of illustration and not by way of limitation.

EXPERIMENTAL

cDNAs encoding two rat homologues of UNC-5, termed UNC5H-1 (SEQ ID NO:1) and UNC5H-2 (SEQ ID NO:2), were isolated from an E18 rat brain cDNA library (see Methods). The predicted proteins (SEQ ID NOS: 3 and 4) show sequence similarity with UNC-5 over their entire lengths, but are more similar to one another (52% identity) than to UNC-5 (28% identity in each case). Like UNC-5¹⁴, both possess two predicted Ig-like domains and two predicted thrombospondin type-1 repeats in their extracellular domains, a predicted membrane spanning region, and a large intracellular domain. The UNC5H proteins also each possess a signal sequence which, curiously, is lacking in UNC-5¹⁴. The predicted topology of the UNC5H proteins in cell membranes was verified using recombinant versions of the proteins expressed

in transfected cells and antibodies directed against the extracellular and intracellular domains (see Methods). The cytoplasmic domains of the two UNC5H proteins do not contain obvious signaling motifs, but do possess a small region of homology to Zona Occludens-1 (ZO-1), a protein that localizes to adherens junctions and is implicated in junction formation^{18, 19}. ZO-1 contains PDZ-domains^{18, 19}, structures implicated in protein clustering²⁰, but the region of
5 homology with UNC-5 homologues corresponds to a unique sequence at the carboxy terminus of ZO-1. The homology between ZO-1 and *C. elegans* UNC-5 is less pronounced (and is not detected by computer BLAST search), but is nonetheless apparent when all four sequences are aligned.

To determine whether the UNC-5 homologues are candidates for receptors involved in
10 neuronal migration or axon guidance, we first examined the sites of expression of *Unc5h-1* and *Unc5h-2* by RNA in situ hybridization in rat embryos. *Unc5h-1* transcripts are detected at early stages of neural tube development in the ventral spinal cord. At embryonic day 11 (E11), when motoneurons are beginning to differentiate in that region²¹, transcripts are present throughout the ventral spinal cord, excluding the midline floor plate region, but are most intense in the
15 ventricular zone and at the lateral edges. At E12, prominent expression is observed in the motor columns, but also extends more dorsally, and is now becoming excluded from the ventricular zone. This more dorsal expression appears transient, as expression by E13 is confined to postmitotic cells in the ventral spinal cord, apparently including the motoneurons. *Unc5h-2* transcripts are not detected at significant levels in the spinal cord until E14, when they are found
20 in the roof plate region. *Unc5h-2* transcripts are, however, detected in developing sensory ganglia that flank the spinal cord, at low levels at E12, and at higher levels by E14. The expression of these two genes is thus observed in regions where differentiating neurons are undergoing axonogenesis, consistent with a possible role in this process.

Expression of these genes is also observed at higher axial levels of the nervous system,
25 as well as in non-neural structures. At E13, *Unc5h-1* is expressed in the basal plate (ventral neural tube) in the hindbrain and midbrain, in the developing hypothalamus and thalamus, and in the pallidum. *Unc5h-2* expression at this stage is detected in the dorsal aspect of the developing optic cup, the nasal pits, apical ridge of the limb bud, urogenital tubercle, and in restricted regions of the midbrain and caudal diencephalon. By E16, *Unc5h-1* mRNA is also
30 detected at high levels in the entorhinal cortex and at lower levels throughout the cortex. *Unc5h-2* is also detected at this stage at low levels in the cortex, and at high levels in hypertrophic

chondrocytes. Expression of the two homologues persists postnatally, with, at postnatal day 10 (P10), continued expression of both at low levels throughout the cortex, expression of both in distinct patterns in the septal area, and high level expression of *Unc5h-1* in the developing hippocampus and entorhinal cortex. In addition, a prominent site of postnatal expression of both genes is in the cerebellum. Both are expressed in the inner granule cell layer, and *Unc5h-2* is in addition expressed in the inner aspect of the external germinal layer, where granule cell precursors differentiate prior to migrating to their final destination in the inner granule cell layer^{22, 23}. Thus, expression of *Unc5h-2* in this region is associated with a prominent cell migration event in the developing cerebellum.

Although the expression patterns of the two UNC5H proteins were suggestive of potential roles in cell or axon migration, to obtain more direct evidence implicating them in mediating responses to netrins we tested whether netrin-1 can bind cells expressing these proteins. Transfected monkey kidney COS-1 cells or human embryonic kidney 293 cells expressing either UNC5H-1 or UNC5H-2 showed significant binding of netrin-1 protein above background, as is also observed for transfected cells expressing the netrin receptors DCC and neogenin, but not for transfected cells expressing TAG-1 or L1, two other members of the Ig superfamily¹³. In these experiments, binding was performed in the presence of soluble heparin, which eliminates non-specific binding of netrin-1 to the cells¹³ but does not evidently prevent binding to the UNC5 homologues. To verify, in the case of UNC5H-2, that exogenously added heparin is not required for the interaction, we generated a soluble protein comprising the extracellular domain of UNC5H-2 fused to the constant region (Fc) of a human immunoglobulin molecule. This UNC5H-2-Fc fusion protein bound transfected 293 cells expressing netrin-1 (some of which remains associated with the surface of these cells^{3, 10}) in the absence of added heparin but did not show binding to non-transfected cells, nor to cells expressing UNC5H-2 itself, DCC, or neogenin. The UNC5H-2-Fc fusion also did not bind transfected cells expressing F-spondin, an adhesive extracellular matrix protein made by floor plate cells²⁴, or Semaphorin III, a chemorepellent for sensory axons at the stages that *Unc5h-2* is expressed in sensory ganglia²⁵. Both of these proteins, like netrin-1, are secreted but partition between cell surfaces and the soluble fraction^{24, 26}. Thus, the interaction between netrin-1 and UNC5H-2 appears specific, and does not require heparin nor reflect a generalized interaction with proteins that associate non-specifically with cell surfaces.

The affinity of UNC-5 homologues for netrin-1 was estimated in equilibrium binding

experiments using netrin(VIov)-Fc, a fusion of the amino terminal two-thirds of netrin-1 to the constant portion of human IgG¹³. This netrin-1 derivative is bioactive but, unlike netrin-1, does not aggregate at high concentrations, and it binds DCC with a Kd comparable to that of full length netrin-1¹³. Specific binding of netrin (VIov)-Fc to each of the three UNC5 homologues showed saturation and the binding curves were fitted to the Hill equation, yielding Kd values of 19 ± 0.8 nM and 3.4 ± 1.0 nM for UNC5H1 and UNC5H2 respectively. These values are comparable to the Kd for the DCC-netrin (VIov)-Fc interaction (~5 nM), and are consistent with the effective dose for the axon outgrowth promoting effects of netrin-1^{2, 13}.

Establishing the involvement of these vertebrate UNC5H proteins in cell migration and axon guidance will require perturbing their functions in vivo. In the meantime, however, our results are at least consistent with such an involvement, as these homologues are expressed by some populations of cells that are undergoing migrations or extending axons. For example, *Unc5h1* is expressed by spinal motoneurons, whose axons are repelled in vitro by floor plate cells²⁷, and whose outgrowth in vitro can be suppressed by netrin-1. It is also expressed in the region of trochlear motoneurons, which can be repelled by netrin-1⁴. Both *Unc5h* genes are also expressed in the developing cerebellum, which is a site of extensive cell migration.

Although the in vivo functions of the UNC-5 homologues described here remain to be determined, our evidence that vertebrate UNC5H proteins bind netrin-1 provides direct support for the idea that members of this new subfamily of the Ig superfamily are netrin receptors. This idea was first proposed for *C. elegans* UNC-5, based on the findings that *unc-5* is required cell-autonomously for dorsal migrations that require the function of the netrin UNC-6¹⁴, and that ectopic expression of *unc-5* in neurons that normally project longitudinally or ventrally can steer their axons dorsally¹⁷. Although consistent with the possibility that UNC-5 is an UNC-6 receptor, these results are also consistent with a role for UNC-5 in modifying the function of a distinct UNC-6 receptor. The possibility of a modifier function was made more plausible by evidence that the DCC homologue UNC-40, which is a putative UNC-6 receptor involved in ventral migrations¹¹, is expressed by axons that project dorsally and is required for those projections^{11, 15, 16}, suggesting that UNC-5 might function by switching an attractive netrin receptor (UNC-40) into a repulsive netrin receptor. However, our results suggest that UNC-5 also functions directly as a netrin receptor. A model in which UNC-40 and UNC-5 can form a receptor complex but UNC-5 can also function alone in transducing the UNC-6 netrin signal provides an explanation for the observation that loss of *unc-40* function results in a much less

severe phenotype for dorsal migrations than do either loss of *unc-5* or loss of *unc-6* function^{15, 16}.

Recent studies have demonstrated a remarkable phylogenetic conservation in function of netrin proteins in guiding axons towards a source of netrin at the midline of the nervous systems of nematodes, flies and vertebrates^{1, 7, 8, 9}, as well as a conserved role for members of the DCC subfamily of the Ig superfamily in mediating the axonal responses that underlie those guidance events^{11, 12, 13}. The identification of vertebrate homologues of UNC-5, and the evidence that they are netrin-binding proteins, suggests that the signaling mechanisms through which netrins elicit repulsive responses are also conserved.

Isolation of rat UNC-5 homologues, and in situ hybridization. A search of the human expressed sequence tag (EST) databases revealed a small sequence (Genbank accession number R11880) with distant similarity to the carboxy-terminal portion of UNC-5. The corresponding cDNA fragment, amplified by polymerase chain reaction from an embryonic human brain cDNA library (Stratagene), was used to screen the library, resulting in the isolation of a 3.8 kB cDNA clone comprising all but the first 440 nt of the coding region of the human homologue of UNC5H1. Non-overlapping probes from this cDNA were used to screen an E18 rat brain library (gift of S. Nakanishi), leading to isolation of seven partial and one full length UNC5H1 cDNA and one full length UNC5H2 cDNA. Additional screens of E13 rat dorsal and ventral spinal cord libraries resulted in isolation of a second full length UNC5H2 cDNA as well as a nearly full length UNC5H1 cDNA. Sequencing was performed on a Licor (L4000) automated sequencer as well as by ³³P cycle sequencing. Genbank accession numbers are U87305 and U87306 for rUNC5H1 and rUNC5H2 respectively. RNA *in situ* hybridization was performed as described¹³.

Antibodies, expression constructs and immunohistochemistry. Rabbit polyclonal antisera were raised to a peptide corresponding to a sequence (YLRKNFEQEPLAKE, SEQ ID NO:7, residues 148-161) in the extracellular domain of UNC5H-2 that is almost completely conserved in UNC5H-1 (one amino acid substitution), and to peptides corresponding to unique sequences in the cytoplasmic domains of UNC5H-1 (GEPSPDSWSLRLKKQ, SEQ ID NO:5, residues 580-594) and UNC5H-2 (EARQQDDGDLNSLASA, SEQ ID NO:7, residues 909-924). Antisera were affinity-purified on the respective peptides (Quality Controlled Biochemicals). cDNAs for the various constructs were subcloned into the COS cell expression vector pMT21 and the 293-EBNA cell expression vector pCEP4 (Invitrogen), and transiently transfected into those cells using lipofectamine. The antiserum to the extracellular peptide can detect both UNC5H proteins

expressed in transfected cells without cell permeabilization, whereas the antisera directed against the cytoplasmic domain peptides detected their respective proteins after cell permeabilization. Netrin-1 protein was produced, purified, used and visualized in binding assays as described¹³, except that a monoclonal antibody (9E10)²⁹ directed to a C-terminal myc-epitope tag was used to detect recombinant netrin-1, and heparin was used at 1 µg/ml. A 293-EBNA cell line stably
 5 expressing the UNC5H-2-Fc fusion was derived and maintained as described^{10, 13}. The fusion protein was purified from serum-free medium conditioned for seven days by affinity chromatography on protein A agarose. The 293 cell line expressing netrin-1 was as described¹³. Binding of the UNC5H-2-Fc fusion to this line was visualized using a Cy3-conjugated secondary antibody (Jackson ImmunoResearch) directed against human Fc.

10 References

1. Ishii, N., et al., *Neuron* 9, 873-81 (1992).
2. Serafini, T. et al. *Cell* 78, 409-24 (1994).
3. Kennedy, T. E., Serafini, T., de la Torre, J. R. & Tessier-Lavigne, M. *Cell* 78, 425-35 (1994).
4. Colamarino, S. A. & Tessier-Lavigne, M. *Cell* 81, 621-9 (1995).
- 15 5. Shirasaki, R., Tamada, A., Katsumata, R. & Murakami, F. *Neuron* 14, 961-72 (1995).
6. Wadsworth, W. G., Bhatt, H. & Hedgecock, E. M. *Neuron* 16, 35-46 (1996).
7. Mitchell, K.J., et al., *Neuron* 17, 203 (1996)
8. Harris, R., Sabatelli, L. M. & Seeger, M. A. *Neuron* 17, 217-228 (1996).
9. Serafini, T., et al., *Cell* in press.
- 20 10. Shirasaki, R., Mirzayan, C., Tessier-Lavigne, M. & Murakami, F. *Neuron* in press, (1996).
11. Chan S. S.-Y., et al., *Cell* 87, 187-196 (1996).
12. Kolodziej, P.A., et al., *Cell* 87, 197-204 (1996)
13. Keino-Masu, K, et al., *Cell* 87, 175-185 (1996).
14. Leung-Hagesteijn, C. et al. *Cell* 71, 289-99 (1992).
- 25 15. Hedgecock, E. M., Culotti, J. G. & Hall, D. H. *Neuron* 4, 61-85 (1990).
16. McIntire, S. L., et al., *Neuron* 8, 307-22 (1992).
17. Hamelin, M., Zhou, Y., Su, M. W., Scott, I. M. & Culotti, J. G. *Nature* 364, 327-30 (1993).
18. Willott E; et al., *Proc. Natl Acad. Sci* 90, 7834-8 (1993).
19. Itoh M; et al., *J. Cell Biol.* 121, 491-502 (1993).
- 30 20. Sheng, M. *Neuron* 17, 575-578 (1996).
21. Altman, J., & Bayer, S.A. *Adv. Anat. Embryol. Cell Biol.* 85, 1-166 (1984).

22. Ramon y Cajal, S. *Histologie du Systeme Nerveux de l'Home et des Vertebres*, Vol. 2 (1911).
23. Rakic, P. J. *Comp. Neurol.* 141, 283-312 (1971).
24. Klar A; Baldassare M; & Jessell TM. *Cell* 69, 95-110. (1992).
25. Messersmith, E. K. *et al. Neuron* 14, 949-59 (1995).
26. Luo, Y., Raible, D. & Raper, J. A. *Cell* 75, 217-27 (1993).
- 5 27. Guthrie, S. & Pini, A. *Neuron* 14, 1117-30 (1995).
28. Evan, G.I., Lewis, G.K., Ramsey, G., & Bishop, J.M. *Mol. Cell. Biol.* 5, 3610-3616 (1985).

EXAMPLES

1. Protocol for high throughput vertebrate UNC-5 - netrin binding assay.
- 10 A. Reagents:
 - Neutralite Avidin: 20 µg/ml in PBS.
 - Blocking buffer: 5% BSA, 0.5% Tween 20 in PBS; 1 hour at room temperature.
 - Assay Buffer: 100 mM KCl, 20 mM HEPES pH 7.6, 1 mM MgCl₂, 1% glycerol, 0.5% NP-40, 50 mM b-mercaptoethanol, 1 mg/ml BSA, cocktail of protease inhibitors.
 - 15 - ³³P vertebrate UNC-5 protein 10x stock: 10⁻⁸ - 10⁻⁶ M "cold" vertebrate UNC-5 supplemented with 200,000-250,000 cpm of labeled vertebrate UNC-51 (Beckman counter). Place in the 4°C microfridge during screening.
 - Protease inhibitor cocktail (1000X): 10 mg Trypsin Inhibitor (BMB # 109894), 10 mg Aprotinin (BMB # 236624), 25 mg Benzamidine (Sigma # B-6506), 25 mg Leupeptin (BMB # 20 1017128), 10 mg APMSF (BMB # 917575), and 2mM NaVO₃ (Sigma # S-6508) in 10 ml of PBS.
 - nerin-1: 10⁻⁷ - 10⁻⁵ M biotinylated netrin-1 in PBS.
- B. Preparation of assay plates:
 - Coat with 120 µl of stock N-Avidin per well overnight at 4°C.
 - Wash 2 times with 200 µl PBS.
 - 25 - Block with 150 µl of blocking buffer.
 - Wash 2 times with 200 µl PBS.
- C. Assay:
 - Add 40 µl assay buffer/well.
 - Add 10 µl compound or extract.
 - 30 - Add 10 µl ³³P-UNC-5 (20-25,000 cpm/0.1-10 pmoles/well = 10⁻⁹ - 10⁻⁷ M final conc).
 - Shake at 25°C for 15 minutes.

- Incubate additional 45 minutes at 25°C.
- Add 40 μ M biotinylated netrin-1 (0.1-10 pmoles/40 μ l in assay buffer)
- Incubate 1 hour at room temperature.
- Stop the reaction by washing 4 times with 200 μ M PBS.
- Add 150 μ M scintillation cocktail.
- 5 - Count in Topcount.

D. Controls for all assays (located on each plate):

- a. Non-specific binding
- b. Soluble (non-biotinylated netrin-1) at 80% inhibition.

10 All publications and patent applications cited in this specification are herein incorporated
by reference as if each individual publication or patent application were specifically and
individually indicated to be incorporated by reference. Although the foregoing invention has
been described in some detail by way of illustration and example for purposes of clarity of
understanding, it will be readily apparent to those of ordinary skill in the art in light of the
15 teachings of this invention that certain changes and modifications may be made thereto without
departing from the spirit or scope of the appended claims.

SEQUENCE LISTING

(1) GENERAL INFORMATION:

(i) APPLICANT: Tessier-Lavigne, Marc

Leonardo, E. David

Hink, Lindsay

Masu, Masayuki

Kazuko, Keino-Masu

(ii) TITLE OF INVENTION: Netrin Receptors

(iii) NUMBER OF SEQUENCES: 8

(iv) CORRESPONDENCE ADDRESS:

(A) ADDRESSEE: SCIENCE & TECHNOLOGY LAW GROUP

(B) STREET: 268 BUSH STREET, SUITE 3200

(C) CITY: SAN FRANCISCO

(D) STATE: CALIFORNIA

(E) COUNTRY: USA

(F) ZIP: 94104

(v) COMPUTER READABLE FORM:

(A) MEDIUM TYPE: Floppy disk

(B) COMPUTER: IBM PC compatible

(C) OPERATING SYSTEM: PC-DOS/MS-DOS

(D) SOFTWARE: PatentIn Release #1.0, Version #1.30

(vi) CURRENT APPLICATION DATA:

(A) APPLICATION NUMBER: US

(B) FILING DATE:

(C) CLASSIFICATION:

(viii) ATTORNEY/AGENT INFORMATION:

(A) NAME: OSMAN, RICHARD A

(B) REGISTRATION NUMBER: 36,627

(C) REFERENCE/DOCKET NUMBER: UC96-217

(ix) TELECOMMUNICATION INFORMATION:

(A) TELEPHONE: (415) 343-4341

(B) TELEFAX: (415) 343-4342

(2) INFORMATION FOR SEQ ID NO:1:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 3014 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: double

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

ATGGCCGTCC	GGCCCGGCCT	GTGGCCAGTG	CTCCTGGGCA	TAGTCCTCGC	CGCCTGGCTT	60
CGTGGTTCGG	GTGCCCAGCA	GAGTGCCACG	GTGGCCAATC	CAGTGCCCGG	TGCCAACCCC	120
GACCTGCTGC	CCCACTTCCT	GGTAGAGCCT	GAGGACGTGT	ACATTGTCAA	GAACAAGCCG	180
GTGTTGTTGG	TGTGCAAGGC	TGTGCCTGCC	ACCCAGATCT	TCTTCAAGTG	CAATGGGGAA	240

	TGGGTCCGCC	AGGTCGATCA	CGTAATTGAA	CGCAGCACCG	ACAGCAGCAG	CGGATTGCCA	300
	ACCATGGAGG	TCCGTATCAA	CGTATCGAGG	CAGCAGGTAG	AGAAAGTGTT	TGGGCTGGAG	360
	GAATACTGGT	GCCAGTGTGT	GGCATGGAGC	TCCTCGGGTA	CCACCAAAAG	TCAGAAGGCC	420
	TACATCCGGA	TTGCCTATTT	GCGCAAGAAC	TTTGAGCAGG	AGCCACTGGC	CAAGGAAGTG	480
	TCACTGGAGC	AAGGCATTGT	ACTACCTTGT	CGCCCCCAG	AAGGAATCCC	CCCAGCTGAG	540
5	GTGGAGTGGC	TTCGAAATGA	GGACCTCGTG	GACCCCTCCC	TCGATCCCAA	TGTGTACATC	600
	ACGCGGGAGC	ACAGCCTAGT	CGTGCGTCAG	GCCCCCTGG	CCGACACGGC	CAACTACACC	660
	TGTGTGGCCA	AGAACATCGT	AGCCCGTCGC	CGAAGCACCT	CTGCAGCGGT	CATTGTTTAT	720
	GTGAACGGTG	GGTGGTCGAC	GTGGACTGAG	TGGTCCGTCT	GCAGCGCCAG	CTGTGGGCGT	780
	GGCTGGCAGA	AACGGAGCCG	GAGCTGCACC	AACCCGGCAC	CTCTCAACGG	GGGCGCCTTC	840
10	TGTGAGGGGC	AGAATGTCCA	GAAAACAGCC	TGCGCCACTC	TGTGCCCAGT	GGATGGGAGC	900
	TGGAGTTCTGT	GGAGTAAGTG	GTCAGCCTGT	GGGCTTGACT	GCACCCACTG	GCGGAGCCGC	960
	GAGTGCTCTG	ACCCAGCAC	CCGCAATGGA	GGTGAGGAGT	GTCGGGGTGC	TGACCTGGAC	1020
	ACCCGCAACT	GTACCAGTGA	CCTCTGCCTG	CACACCGCTT	CTTGCCCCGA	GGACGTGGCT	1080
	CTCTACATCG	GCCTTGTCGC	TGTGGCTGTG	TGCCCTTTCT	TGCTGTTGCT	GGCCCTTGGA	1140
15	CTCATTTACT	GTCGCAAGAA	GGAAGGGCTG	GACTCCGATG	TGGCCGACTC	GTCCATCCTC	1200
	ACCTCGGGCT	TCCAGCCTGT	CAGCATCAAG	CCCAGCAAAG	CAGACAACCC	CCACCTGCTC	1260
	ACCATCCAGC	CAGACCTCAG	CACCACCACT	ACCACCTACC	AGGGCAGTCT	ATGTTTCGAGG	1320
	CAGGATGGAC	CCAGCCCCAA	GTTCCAGCTC	TCTAATGGTC	ACCTGCTCAG	CCCACTGGGG	1380
	AGTGCCCGCC	ATACGTTGCA	CCACAGCTCA	CCCACCTCTG	AGGCTGAGGA	CTTCGTCTCC	1440
20	CGCCTCTCCA	CCCAAACTA	CTTTCGTTCC	CTGCCCGCG	GCACCAGCAA	CATGGCCTAC	1500
	GGGACCTTCA	ACTTCTCTCG	GGGCCGGCTG	ATGATCCCTA	ATACGGGGAT	CAGCCTCCTC	1560
	ATACCCCGCG	ATGCCATCCC	CCGAGGAAAG	ATCTACGAGA	TCTACCTCAC	ACTGCACAAG	1620
	CCAGAAGACG	TGAGGTTGCC	CCTAGCTGGC	TGTCAGACCC	TGCTGAGTCC	AGTCGTTAGC	1680
	TGTGGGCCCC	CAGGAGTCCT	GCTCACCCGG	CCAGTCATCC	TTGCAATGGA	CCACTGTGGA	1740
25	GAGCCCAGCC	CTGACAGCTG	GAGTCTGCGC	CTCAAAAAGC	AGTCCTGCGA	GGGCAGTTGG	1800
	GAGGATGTGC	TGCACCTTGG	TGAGGAGTCA	CCTTCCCACC	TCTACTACTG	CCAGCTGGAG	1860
	GCCGGGGCCT	GCTATGTCTT	CACGGAGCAG	CTGGGCCGCT	TTGCCCTGGT	AGGAGAGGCC	1920
	CTCAGCGTGG	CTGCCACCAA	GCGCCTCAGG	CTCCTTCTGT	TTGCTCCCGT	GGCCTGTACG	1980
	TCCCTTGAGT	ACAACATCCG	AGTGTACTGC	CTACACGACA	CCCACGACGC	TCTCAAGGAG	2040
30	GTGGTGACG	TGGAGAAGCA	GCTAGGTGGA	CAGCTGATCC	AGGAGCCTCG	CGTCTGCAC	2100
	TTCAAAGACA	GTTACCACAA	CCTACGTCTC	TCCATCCACG	ACGTGCCCAG	CTCCCTGTGG	2160
	AAGAGCAAGC	TACTTGTCAG	CTACCAGGAG	ATCCCTTTTT	ACCACATCTG	GAACGGCACC	2220
	CAGCAGTATC	TGCACTGCAC	CTTCACCCTG	GAGCGCATCA	ACGCCAGCAC	CAGCGACCTG	2280
	GCCTGCAAGG	TGTGGGTGTG	GCAGGTGGAG	GGAGATGGGC	AGAGCTTCAA	CATCAACTTC	2340
35	AACATCACTA	AGGACACAAG	GTTTGCTGAA	TTGTTGGCTC	TGGAGAGTGA	AGGGGGGGTC	2400
	CCAGCCCTGG	TGGGCCCCAG	TGCCTTCAAG	ATCCCTTCC	TCATTGCGCA	AAAGATCATC	2460
	GCCAGTCTGG	ACCCACCCTG	CAGCCGGGGC	GCCGACTGGA	GAACCTTAGC	CCAGAAACTT	2520
	CACCTGGACA	GCCATCTTAG	CTTCTTTGCC	TCCAAGCCCA	GCCCTACAGC	CATGATCCTC	2580
	AACCTATGGG	AGGCACGGCA	CTTCCCCAAC	GGCAACCTCG	GCCAGCTGGC	AGCAGCTGTG	2640
40	GCCGGACTGG	GCCAACCAGA	TGCTGGCCTC	TTCACGGTGT	CGGAGGCCGA	GTGTTGAGAC	2700
	CAGCCAGGCC	GGTAATGCCT	ACATTCTCAC	CAGCTTTGAC	ACCTGCCAGG	GACAGGCAAA	2760
	ACCAGACAGG	GGCCCTTCCC	CCACACCCGG	GGAGAGCTGC	TTGGACAGGC	CCCCTCCTGG	2820
	TGAAGTTGTC	CCTCGATGCT	GGTCCTTCAG	ACCCTGCCCA	AACTCCATCC	CTCCATGGCC	2880
	TGCCCCGCCA	GGTTGGTCTA	GCCACCTGCT	CTCACTCTGC	CCTGGTCCCA	GGGCCAGAGT	2940

AGACAGTCCT GGAGCCTGGG CTGAGCCTCG CCAGCCCATC TGTGTGTGTG TGTATATGCG 3000
TGTATGCTAC CTCT 3014

(2) INFORMATION FOR SEQ ID NO:2:

(i) SEQUENCE CHARACTERISTICS:

- 5 (A) LENGTH: 1787 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: double
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

10 (xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

GCAACTGTAC CAGTGACCTC TGGTACACAC TGCTTCTGGC CCTGAGGACG TGGCCCTCTA 60
TGTGGGCCTC ATCGCCGTGG CCGTCTGCCT GGTCTGTGTC CTGCTTGTCC TCATCCTCGT 120
TTATTGCCGG AAGAAGGAGG GGCTGGACTC AGATGTGGCT GACTCGTCCA TTCTCACCTC 180
AGGCTTCCAG CCCGTAGCA TCTAAGCCCA GCAAAGCAGA CAACCCCCAT CTGCTACCA 240
15 TCCAGCCGGA CCTCAGCACC ACCACCACCA CCTACCAGGG CAGTCTCTGT CCCCGGCAGG 300
ATGGGCCCAG CCCCAAGTTC CAGCTCACCA ATGGGCACCT GCTCAGCCCC CTGGGTGGCG 360
GCCGCCACAC ACTGCACCAC AGCTCTCCCA CCTCTGAGGC CGAGGAGTTC GTCTCCCGCC 420
TCTCCACCCA GAACTACTTC CGCTCCCTGC CCCGAGGCAC CAGCAACATG ACCTATGGGA 480
CCTTCAACTT CCTCGGGGGC CGGCTGATGA TCCCTAATAC AGGAATCAGC CTCCTCATCC 540
20 CCCCAGATGC CATACCCCGA GGAAGATCT ATGAGATCTA CCTCACGCTG CACAAGCCGG 600
AAGACGTGAG GTTGGCCCTA GCTGGCTGTC AGACCCTGCT GAGTCCCATC GTTAGCTGTG 660
GACCCCTGG CGTCTGCTC ACCCGGCCAG TCATCCTGGC TATGGACCAC TGTGGGAGC 720
CCAGCCCTGA CAGCTGGAGC CTGGCCCTCA AAAAGCAGTC GTGCGAGGGA GCTGGGAGGA 780
TGTCTGCACC TGGCGGAGGA GGCGCCCTCC CACCTCTACT ACTGCCAGCT GGAGGCCAGT 840
25 GCCTGCTACG TCTTCACCGA GCAGCTGGGC CGCTTTGCCC TGGTGGGAGA GGCCCTCAGC 900
GTGGTGCCG CCAAGCGCCT CAAGCTGCTT CTGTTTGC GC GGTGGCCTG CACCTCCCTC 960
GAGTACAACA TCCGGGTCTA CTGCCTGCAT GACACCCACG ATGCACTCAA GGAGGTGGTG 1020
CAGCTGGAGA AGCAGCTGGG GGGACAGCTG ATCCAGGAGC CACGGGTCCT GCACCTAAGG 1080
ACAGTTACCA CAACCTGCCC TATCATCCAC GATGTGCCCA GCTCCCTGTG GAAGAGTAAG 1140
30 CTCCTTGTCA GCTACCAGGA GATCCCTTT TATCACATCT GGAATGGCAC GCAGCGGTAC 1200
TTGCACTGCA CCTTCACCTT GGAGCGTGTC AGCCCCAGCA CTAGTGACCT GGCTGCAAG 1260
CTGTGGGTGT GGCAGGTGGA GGGCGACGGG CAGAGCTTCA GCATCAACTT CAACATCACC 1320
AAGGACACAA GGTTTGCTGA GCTGCTGGCT CTGGAGAGTG AAGCGGGGT CCCAGCCCTG 1380
GTGGGCCCCA GTGCCTTCAA GATCCCTTTC CTCATTGCGC AGAAGATAAT TTCCAGCCTG 1440
35 GACCCACCTT GTAGGCGGGG TGCCGACTGG CGGACTCTGG CCCAGAACT CCACCTGGAC 1500
AGCCATCTCA GCTTCTTTGC CTCGAAGCCC AGCCCCACAG CCATGATCCT CAACCTGTGG 1560
GAGGCGCGGC ACTTCCCCAA CGGCAACCTC AGCCAGCTGG CTGCAGCAGT GGCTGGGACT 1620
GGCCAGCAGG ACGGTGGCTT CTTTCACAGT GTTCGGAGGC TGAGTGCTGA GGCCGGCCAG 1680
GCGAACACTA CAATTTTACC AGTTTGGGA ACCCACCAGG GGACAGGCAG AAGCCGGACA 1740
40 AGGGCTTTTC CAAAACCGG GGAGAGTTTT TTTGAAAAG GCCTTTT 1787

(2) INFORMATION FOR SEQ ID NO:3:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 2831 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: double

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

5	ATGAGGGCCC GGAGCGGCGG GGCCGCTGCT GTGGCGCTGC TGCTCTGCTG GGATCCGACA	60
	CCGAGCTTAG CAGGCATTGA CTCTGGTGCC CAGGGACTCC CAGACTCCTT CCCATCAGCA	120
	CCCGCGGAGC AGCTGCCTCA CTTCCTGCTG GAACCAGAGG ATGCCTACAT CGTAAAGAAC	180
	AAGCCAGTGG AATPGCACTG CCGAGCCTTC CCTGCCACAC AGATCTACTT CAAGTGTAAAT	240
	GGCGAGTGGG TTAGCCAGAA AGGCCACGTC ACGCAGGAGA GCCTGGATGA GGCCACAGGC	300
10	TTGCGAATAC GAGAGGTGCA GATAGAGGTG TCGCGGCAGC AGGTGGAGGA ACTTTTGGG	360
	CTCGAGGACT ACTGGTGTC A GTGCGTGCC TGGAGCTCTT CGGGAACCAC CAAGAGTCGC	420
	CGAGCCTACA TCCGCATTGC CTACTTGCGC AAGAACTTTG ACCAGGAGCC TCTGGCGAAG	480
	GAGGTACCTT TGGATCATGA GGTCTTCTG CAGTGCCGCC CACCAGAGGG AGTGCCTGTG	540
	GCTGAGGTGG AATGGCTCAA GAATGAAGAT GTCATCGATC CCGCTCAGGA CACTAACTTC	600
15	CTGCTCACCA TTGACCACAA CCTCATCATC CGCCAGGCGC GCCTCTCAGA CACAGCCAAC	660
	TACACCTGTG TGGCAAAGAA TATTGTGGCC AAGCGCCGGA GCACGACGGC CACAGTCATC	720
	GTCTATGTGA ACGGAGGTTG GTCCAGCTGG GCAGAATGGT CACCCTGCTC TAACCGCTGC	780
	GGCCGAGGTT GGCAGAAACG TACTAGGACC TGCACCAACC CAGCCCCACT CAATGGAGGT	840
	GCCTTCTGCG AGGGACAGGC TTGCCAGAAG ACGGCTTGCA CCACCGTGTG CCCAGTGGAT	900
20	GGAGCGTGA CTGAGTGGAG CAAGTGGTCC GCCTGCAGCA CAGAGTGTGC GCACTGGCGC	960
	AGCCGCGAGT GCATGGCACC GCCGCCCCAG AACGGAGGCC GTGACTGCAG CGGGACGCTA	1020
	CTTGACTCCA AGAACTGCAC CGATGGGCTG TGCGTGCTGA ATCAGAGAAC TCTAAACGAC	1080
	CCTAAAAGCC GCCCCTGGA GCCGTCGGGA GACGTGGCGC TGTATGCGGG CCTCGTGGTG	1140
	GCCGTCTTTG TGGTTCTGGC AGTTCTCATG GCTGTAGGAG TGATCGTGTA CCGGAGAAAC	1200
25	TGCCGGGACT TCGACACGGA CATCACTGAC TCCTCTGCTG CCCTCACTGG TGGTTTCCAC	1260
	CCCGTCAACT TCAAGACTGC AAGGCCCAGC AACCCACAGC TCCTGCACCC ATCCGCCCTT	1320
	CCGGACCTAA CGGCCAGTGC TGGCATCTAC CGCGGACCTG TGTATGCCCT GCAGGACTCT	1380
	GCCGACAAGA TCCCTATGAC TAATTACCC CTTCTGGATC CCTTGCCCAG CCTCAAGATC	1440
	AAGGTCTATG ACTCCAGCAC CATCGGCTCT GGGGCTGGCC TGGCTGATGG AGCCGACCTG	1500
30	CTGGGTGTCT TACCACCCGG TACATACCCA GCGGATTTCT CCCGGGACAC CCACTTCCTG	1560
	CACCTGCGCA GCGCCAGCCT TGGTTCCTAG CACCTCCTGG GCCTCCCTCG AGACCCACAGC	1620
	AGCAGTGTCA GTGGACCTT TGGTTGCCTG GGTGGGAGGC TGACCATTC CCGCACAGGG	1680
	GTCAGCCTGT TGGTACCAAA TGGAGCCATT CCCAGGGCA AGTTCTATGA CTTGTATCTA	1740
	CGTATCAACA AGACTGAAAG CACCCTCCCA CTTTCGGAAG GTTCCCAGAC AGTATTGAGC	1800
35	CCCTCGGTGA CCTGCGGGCC CACGGGCCTC CTCCTGTGCC GCCCTGTTGT CTTCACTGTG	1860
	CCCCACTGTG CTGAAGTCAT TGCCGGAGAC TGGATCTTCC AGCTCAAGAC CCAGGCCCAT	1920
	CAGGGCCACT GGGAGGAGGT GGTGACTTTG GATGAGGAGA CTCTGAACAC CCCCTGCTAC	1980
	TGCCAGCTAG AGGCTAAATC CTGCCACATC CTGTTGGACC AGCTGGGTAC CTACGTGTTT	2040
	ACGGGCGAGT CCTACTCCCG CTCGCAGTC AAGCGGCTCC AGCTAGCCAT CTTGCCCCCA	2100
40	GCCCTCTGCA CCTCCCTGGA GTATAGTCTC AGGGTCTACT GTCTGGAGGA CACTCCTGCA	2160
	GCACTGAAGG AGGTCCTAGA GCTGGAGAGG ACTCTGGGTG GCTACTTGGT GGAGGAGCCC	2220
	AAGACTTTGC TCTTTAAGGA CAGTTACCAC AACCTACGCT CTCCCTCCAT GACATCCCCC	2280
	ATGCCCACTG GAGGAGCAAA CTACTGGCCA AGTACCAGGA GATTCCCTTC TACCATGTGT	2340
	GGAACGGCAG CCAGAAAGCC CTGCACTGCA CTTTACCCTT GGAGAGACAT AGCCTAGCCT	2400

CCACTGAGTT CACCTGTAAG GTCTGCGTGC GGCAGGTAGA AGGGGAAGGC CAGATTTTCC 2460
 AGCTGCACAC CACGCTGGCT GAGACGCCTG CTGGCTCCCT GGATGCACTC TGCTCTGCCC 2520
 CTGGCAATGC TGCCACCACA CAGCTGGGAC CCTATGCCTT CAAGATACCA CTGTCCATCC 2580
 GCCAGAAGAT CTGCAACAGC CTGGACGCCC CCAACTCACG GGGCAATGAC TGGCGGCTGT 2640
 TGGCACAGAA GCTCTCCATG GACCGGTACC TGAAC TACTT CGCCACCAAA GCTAGTCCCA 2700
 5 CAGGCGTGAT CTTAGACCTC TGGGAAGCTC GGCAGCAGGA TGATGGGGAC CTCAACAGCC 2760
 TGGCCAGTGC CTTGGAGGAG ATGGGCAAGA GTGAGATGCT GGTAGCCATG ACCACTGATG 2820
 GCGATTGCTG A 2831

(2) INFORMATION FOR SEQ ID NO:4:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 305 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: double
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:

TGGATGAGGA GACCCTGAAC ACACCCTGCT ACTGCAGCTG GAGCCCAGGG CCTGTACATC 60
 CTGCTGGACC AGCTGGGCAC CTACGTTTTC ACGGGCGAGT CCTATTCCCG CTCAGCAGTC 120
 AAGCGGCTCC AGCTGGCCGT TTCGCCCCCG CCCTCTGCAC CTCCCTGGAG TACAGCCTCC 180
 20 GGGTCTACTG CCTGGAGGAC ACGCCTGTAG CACTGAAGGA GGTGCTGGAG CTGGAGCGGA 240
 CTCTGGGCGG ATACTTGGTG GAGGAGCCGA AACCGCTAAT GTTCAAGGAC AGTTACCACA 300
 ACCTT 305

(2) INFORMATION FOR SEQ ID NO:5:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 898 amino acids
 (B) TYPE: amino acid
 (C) STRANDEDNESS: not relevant
 (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: peptide

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:

Met Ala Val Arg Pro Gly Leu Trp Pro Val Leu Leu Gly Ile Val Leu
 1 5 10 15
 Ala Ala Trp Leu Arg Gly Ser Gly Ala Gln Gln Ser Ala Thr Val Ala
 20 25 30
 Asn Pro Val Pro Gly Ala Asn Pro Asp Leu Leu Pro His Phe Leu Val
 35 40 45
 Glu Pro Glu Asp Val Tyr Ile Val Lys Asn Lys Pro Val Leu Leu Val
 50 55 60
 40 Cys Lys Ala Val Pro Ala Thr Gln Ile Phe Phe Lys Cys Asn Gly Glu
 65 70 75 80
 Trp Val Arg Gln Val Asp His Val Ile Glu Arg Ser Thr Asp Ser Ser
 85 90 95
 Ser Gly Leu Pro Thr Met Glu Val Arg Ile Asn Val Ser Arg Gln Gln

	100		105		110
	Val Glu Lys Val Phe Gly Leu Glu Glu Tyr Trp Cys Gln Cys Val Ala				
	115		120		125
	Trp Ser Ser Ser Gly Thr Thr Lys Ser Gln Lys Ala Tyr Ile Arg Ile				
	130		135		140
5	Ala Tyr Leu Arg Lys Asn Phe Glu Gln Glu Pro Leu Ala Lys Glu Val				
	145		150		155
	Ser Leu Glu Gln Gly Ile Val Leu Pro Cys Arg Pro Pro Glu Gly Ile				
	165		170		175
	Pro Pro Ala Glu Val Glu Trp Leu Arg Asn Glu Asp Leu Val Asp Pro				
10	180		185		190
	Ser Leu Asp Pro Asn Val Tyr Ile Thr Arg Glu His Ser Leu Val Val				
	195		200		205
	Arg Gln Ala Arg Leu Ala Asp Thr Ala Asn Tyr Thr Cys Val Ala Lys				
	210		215		220
15	Asn Ile Val Ala Arg Arg Arg Ser Thr Ser Ala Ala Val Ile Val Tyr				
	225		230		235
	Val Asn Gly Gly Trp Ser Thr Trp Thr Glu Trp Ser Val Cys Ser Ala				
	245		250		255
	Ser Cys Gly Arg Gly Trp Gln Lys Arg Ser Arg Ser Cys Thr Asn Pro				
20	260		265		270
	Ala Pro Leu Asn Gly Gly Ala Phe Cys Glu Gly Gln Asn Val Gln Lys				
	275		280		285
	Thr Ala Cys Ala Thr Leu Cys Pro Val Asp Gly Ser Trp Ser Ser Trp				
	290		295		300
25	Ser Lys Trp Ser Ala Cys Gly Leu Asp Cys Thr His Trp Arg Ser Arg				
	305		310		315
	Glu Cys Ser Asp Pro Ala Pro Arg Asn Gly Gly Glu Glu Cys Arg Gly				
	325		330		335
	Ala Asp Leu Asp Thr Arg Asn Cys Thr Ser Asp Leu Cys Leu His Thr				
30	340		345		350
	Ala Ser Cys Pro Glu Asp Val Ala Leu Tyr Ile Gly Leu Val Ala Val				
	355		360		365
	Ala Val Cys Leu Phe Leu Leu Leu Leu Ala Leu Gly Leu Ile Tyr Cys				
35	370		375		380
	Arg Lys Lys Glu Gly Leu Asp Ser Asp Val Ala Asp Ser Ser Ile Leu				
	385		390		395
	Thr Ser Gly Phe Gln Pro Val Ser Ile Lys Pro Ser Lys Ala Asp Asn				
	405		410		415
40	Pro His Leu Leu Thr Ile Gln Pro Asp Leu Ser Thr Thr Thr Thr Thr				
	420		425		430
	Tyr Gln Gly Ser Leu Cys Ser Arg Gln Asp Gly Pro Ser Pro Lys Phe				
	435		440		445
	Gln Leu Ser Asn Gly His Leu Leu Ser Pro Leu Gly Ser Gly Arg His				

21

Gln Lys Ile Ile Ala Ser Leu Asp Pro Pro Cys Ser Arg Gly Ala Asp
 820 825 830
 Trp Arg Thr Leu Ala Gln Lys Leu His Leu Asp Ser His Leu Ser Phe
 835 840 845
 Phe Ala Ser Lys Pro Ser Pro Thr Ala Met Ile Leu Asn Leu Trp Glu
 5 850 855 860
 Ala Arg His Phe Pro Asn Gly Asn Leu Gly Gln Leu Ala Ala Val
 865 870 875 880
 Ala Gly Leu Gly Gln Pro Asp Ala Gly Leu Phe Thr Val Ser Glu Ala
 885 890 895
 10 Glu Cys

(2) INFORMATION FOR SEQ ID NO:6:

(i) SEQUENCE CHARACTERISTICS:

- 15 (A) LENGTH: 557 amino acids
 (B) TYPE: amino acid
 (C) STRANDEDNESS: not relevant
 (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: peptide

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:6:

20 Asn Cys Thr Ser Asp Leu Xaa Val His Thr Ala Ser Gly Pro Glu Asp
 1 5 10 15
 Val Ala Leu Tyr Val Gly Leu Ile Ala Val Ala Val Cys Leu Val Leu
 20 25 30
 25 Leu Leu Leu Val Leu Ile Leu Val Tyr Cys Arg Lys Lys Glu Gly Leu
 35 40 45
 Asp Ser Asp Val Ala Asp Ser Ser Ile Leu Thr Ser Gly Phe Gln Pro
 50 55 60
 Val Ser Ile Lys Pro Ser Lys Ala Asp Asn Pro His Leu Leu Thr Ile
 65 70 75 80
 30 Gln Pro Asp Leu Ser Thr Thr Thr Thr Thr Tyr Gln Gly Ser Leu Cys
 85 90 95
 Pro Arg Gln Asp Gly Pro Ser Pro Lys Phe Gln Leu Thr Asn Gly His
 100 105 110
 35 Leu Leu Ser Pro Leu Gly Gly Gly Arg His Thr Leu His His Ser Ser
 115 120 125
 Pro Thr Ser Glu Ala Glu Glu Phe Val Ser Arg Leu Ser Thr Gln Asn
 130 135 140
 Tyr Phe Arg Ser Leu Pro Arg Gly Thr Ser Asn Met Thr Tyr Gly Thr
 145 150 155 160
 40 Phe Asn Phe Leu Gly Gly Arg Leu Met Ile Pro Asn Thr Gly Ile Ser
 165 170 175
 Leu Leu Ile Pro Pro Asp Ala Ile Pro Arg Gly Lys Ile Tyr Glu Ile
 180 185 190
 Tyr Leu Thr Leu His Lys Pro Glu Asp Val Arg Leu Pro Leu Ala Gly

	195		200		205
	Cys Gln Thr Leu Leu Ser	Pro Ile Val Ser Cys Gly	Pro Pro Gly Val		
	210	215	220		
	Leu Leu Thr Arg Pro Val	Ile Leu Ala Met Asp His Cys Gly Glu Pro			
	225	230	235	240	
5	Ser Pro Asp Ser Trp Ser	Leu Ala Leu Lys Lys Gln Ser Cys Glu Gly			
	245	250	255		
	Ser Trp Glu Asp Val Leu	His Leu Gly Glu Glu Ala Pro Ser His Leu			
	260	265	270		
10	Tyr Tyr Cys Gln Leu Glu	Ala Ser Ala Cys Tyr Val Phe Thr Glu Gln			
	275	280	285		
	Leu Gly Arg Phe Ala Leu	Val Gly Glu Ala Leu Ser Val Ala Ala Ala			
	290	295	300		
	Lys Arg Leu Lys Leu Leu	Leu Phe Ala Pro Val Ala Cys Thr Ser Leu			
	305	310	315	320	
15	Glu Tyr Asn Ile Arg Val	Tyr Cys Leu His Asp Thr His Asp Ala Leu			
	325	330	335		
	Lys Glu Val Val Gln Leu	Glu Lys Gln Leu Gly Gly Gln Leu Ile Gln			
	340	345	350		
20	Glu Pro Arg Val Leu His	Leu Xaa Asp Ser Tyr His Asn Leu Xaa Leu			
	355	360	365		
	Ser Xaa His Asp Val Pro	Ser Ser Leu Trp Lys Ser Lys Leu Leu Val			
	370	375	380		
	Ser Tyr Gln Glu Ile Pro	Phe Tyr His Ile Trp Asn Gly Thr Gln Arg			
	385	390	395	400	
25	Tyr Leu His Cys Thr Phe	Thr Leu Glu Arg Val Ser Pro Ser Thr Ser			
	405	410	415		
	Asp Leu Ala Cys Lys Leu	Trp Val Trp Gln Val Glu Gly Asp Gly Gln			
	420	425	430		
30	Ser Phe Ser Ile Asn Phe	Asn Ile Thr Lys Asp Thr Arg Phe Ala Glu			
	435	440	445		
	Leu Leu Ala Leu Glu Ser	Glu Ala Gly Val Pro Ala Leu Val Gly Pro			
	450	455	460		
	Ser Ala Phe Lys Ile Pro	Phe Leu Ile Arg Gln Lys Ile Ile Ser Ser			
	465	470	475	480	
35	Leu Asp Pro Pro Cys Arg	Arg Gly Ala Asp Trp Arg Thr Leu Ala Gln			
	485	490	495		
	Lys Leu His Leu Asp Ser	His Leu Ser Phe Phe Ala Ser Lys Pro Ser			
	500	505	510		
40	Pro Thr Ala Met Ile Leu	Asn Leu Trp Glu Ala Arg His Phe Pro Asn			
	515	520	525		
	Gly Asn Leu Ser Gln Leu	Ala Ala Val Ala Gly Thr Xaa Pro Ala			
	530	535	540		
	Gly Arg Trp Leu Leu Ser	Gln Cys Ser Glu Ala Glu Cys			
	545	550	555		

(2) INFORMATION FOR SEQ ID NO:7:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 943 amino acids

(B) TYPE: amino acid

(C) STRANDEDNESS: not relevant

(D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: peptide

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:7:

5 Met Arg Ala Arg Ser Gly Gly Ala Ala Val Ala Leu Leu Leu Cys
 10 1 5 10 15
 Trp Asp Pro Thr Pro Ser Leu Ala Gly Ile Asp Ser Gly Ala Gln Gly
 20 25 30
 Leu Pro Asp Ser Phe Pro Ser Ala Pro Ala Glu Gln Leu Pro His Phe
 35 40 45
 15 Leu Leu Glu Pro Glu Asp Ala Tyr Ile Val Lys Asn Lys Pro Val Glu
 50 55 60
 Leu His Cys Arg Ala Phe Pro Ala Thr Gln Ile Tyr Phe Lys Cys Asn
 65 70 75 80
 Gly Glu Trp Val Ser Gln Lys Gly His Val Thr Gln Glu Ser Leu Asp
 20 85 90 95
 Glu Ala Thr Gly Leu Arg Ile Arg Glu Val Gln Ile Glu Val Ser Arg
 100 105 110
 Gln Gln Val Glu Glu Leu Phe Gly Leu Glu Asp Tyr Trp Cys Gln Cys
 115 120 125
 25 Val Ala Trp Ser Ser Ser Gly Thr Thr Lys Ser Arg Arg Ala Tyr Ile
 130 135 140
 Arg Ile Ala Tyr Leu Arg Lys Asn Phe Asp Gln Glu Pro Leu Ala Lys
 145 150 155 160
 Glu Val Pro Leu Asp His Glu Val Leu Leu Gln Cys Arg Pro Pro Glu
 30 165 170 175
 Gly Val Pro Val Ala Glu Val Glu Trp Leu Lys Asn Glu Asp Val Ile
 180 185 190
 Asp Pro Ala Gln Asp Thr Asn Phe Leu Leu Thr Ile Asp His Asn Leu
 195 200 205
 35 Ile Ile Arg Gln Ala Arg Leu Ser Asp Thr Ala Asn Tyr Thr Cys Val
 210 215 220
 Ala Lys Asn Ile Val Ala Lys Arg Arg Ser Thr Thr Ala Thr Val Ile
 225 230 235 240
 Val Tyr Val Asn Gly Gly Trp Ser Ser Trp Ala Glu Trp Ser Pro Cys
 40 245 250 255
 Ser Asn Arg Cys Gly Arg Gly Trp Gln Lys Arg Thr Arg Thr Cys Thr
 260 265 270
 Asn Pro Ala Pro Leu Asn Gly Gly Ala Phe Cys Glu Gly Gln Ala Cys
 275 280 285

	Gln	Lys	Thr	Ala	Cys	Thr	Thr	Val	Cys	Pro	Val	Asp	Gly	Ala	Trp	Thr
	290						295					300				
	Glu	Trp	Ser	Lys	Trp	Ser	Ala	Cys	Ser	Thr	Glu	Cys	Ala	His	Trp	Arg
	305					310					315					320
5	Ser	Arg	Glu	Cys	Met	Ala	Pro	Pro	Pro	Gln	Asn	Gly	Gly	Arg	Asp	Cys
					325					330					335	
	Ser	Gly	Thr	Leu	Leu	Asp	Ser	Lys	Asn	Cys	Thr	Asp	Gly	Leu	Cys	Val
				340					345					350		
	Leu	Asn	Gln	Arg	Thr	Leu	Asn	Asp	Pro	Lys	Ser	Arg	Pro	Leu	Glu	Pro
		355						360					365			
10	Ser	Gly	Asp	Val	Ala	Leu	Tyr	Ala	Gly	Leu	Val	Val	Ala	Val	Phe	Val
	370						375					380				
	Val	Leu	Ala	Val	Leu	Met	Ala	Val	Gly	Val	Ile	Val	Tyr	Arg	Arg	Asn
	385					390				395						400
	Cys	Arg	Asp	Phe	Asp	Thr	Asp	Ile	Thr	Asp	Ser	Ser	Ala	Ala	Leu	Thr
15					405					410						415
	Gly	Gly	Phe	His	Pro	Val	Asn	Phe	Lys	Thr	Ala	Arg	Pro	Ser	Asn	Pro
					420				425					430		
	Gln	Leu	Leu	His	Pro	Ser	Ala	Pro	Pro	Asp	Leu	Thr	Ala	Ser	Ala	Gly
		435					440						445			
20	Ile	Tyr	Arg	Gly	Pro	Val	Tyr	Ala	Leu	Gln	Asp	Ser	Ala	Asp	Lys	Ile
	450						455					460				
	Pro	Met	Thr	Asn	Ser	Pro	Leu	Leu	Asp	Pro	Leu	Pro	Ser	Leu	Lys	Ile
	465					470					475					480
	Lys	Val	Tyr	Asp	Ser	Ser	Thr	Ile	Gly	Ser	Gly	Ala	Gly	Leu	Ala	Asp
25					485					490						495
	Gly	Ala	Asp	Leu	Leu	Gly	Val	Leu	Pro	Pro	Gly	Thr	Tyr	Pro	Gly	Asp
		500							505					510		
	Phe	Ser	Arg	Asp	Thr	His	Phe	Leu	His	Leu	Arg	Ser	Ala	Ser	Leu	Gly
		515					520						525			
30	Ser	Gln	His	Leu	Leu	Gly	Leu	Pro	Arg	Asp	Pro	Ser	Ser	Ser	Val	Ser
	530						535					540				
	Gly	Thr	Phe	Gly	Cys	Leu	Gly	Gly	Arg	Leu	Thr	Ile	Pro	Gly	Thr	Gly
	545					550					555					560
	Val	Ser	Leu	Leu	Val	Pro	Asn	Gly	Ala	Ile	Pro	Gln	Gly	Lys	Phe	Tyr
35					565					570						575
	Asp	Leu	Tyr	Leu	Arg	Ile	Asn	Lys	Thr	Glu	Ser	Thr	Leu	Pro	Leu	Ser
		580							585					590		
	Glu	Gly	Ser	Gln	Thr	Val	Leu	Ser	Pro	Ser	Val	Thr	Cys	Gly	Pro	Thr
		595						600					605			
40	Gly	Leu	Leu	Leu	Cys	Arg	Pro	Val	Val	Leu	Thr	Val	Pro	His	Cys	Ala
	610						615					620				
	Glu	Val	Ile	Ala	Gly	Asp	Trp	Ile	Phe	Gln	Leu	Lys	Thr	Gln	Ala	His
	625					630					635					640
	Gln	Gly	His	Trp	Glu	Glu	Val	Val	Thr	Leu	Asp	Glu	Glu	Thr	Leu	Asn

						645											655
	Thr	Pro	Cys	Tyr	Cys	Gln	Leu	Glu	Ala	Lys	Ser	Cys	His	Ile	Leu	Leu	
						660				665							670
	Asp	Gln	Leu	Gly	Thr	Tyr	Val	Phe	Thr	Gly	Glu	Ser	Tyr	Ser	Arg	Ser	
						675				680							685
5	Ala	Val	Lys	Arg	Leu	Gln	Leu	Ala	Ile	Phe	Ala	Pro	Ala	Leu	Cys	Thr	
						690				695							700
	Ser	Leu	Glu	Tyr	Ser	Leu	Arg	Val	Tyr	Cys	Leu	Glu	Asp	Thr	Pro	Ala	
	705					710						715					720
	Ala	Leu	Lys	Glu	Val	Leu	Glu	Leu	Glu	Arg	Thr	Leu	Gly	Gly	Tyr	Leu	
10						725					730						735
	Val	Glu	Glu	Pro	Lys	Thr	Leu	Leu	Phe	Lys	Asp	Ser	Tyr	His	Asn	Leu	
						740				745							750
	Arg	Leu	Ser	Leu	His	Asp	Ile	Pro	His	Ala	His	Trp	Arg	Ser	Lys	Leu	
						755				760							765
15	Leu	Ala	Lys	Tyr	Gln	Glu	Ile	Pro	Phe	Tyr	His	Val	Trp	Asn	Gly	Ser	
						770				775							780
	Gln	Lys	Ala	Leu	His	Cys	Thr	Phe	Thr	Leu	Glu	Arg	His	Ser	Leu	Ala	
	785					790						795					800
	Ser	Thr	Glu	Phe	Thr	Cys	Lys	Val	Cys	Val	Arg	Gln	Val	Glu	Gly	Glu	
20						805					810						815
	Gly	Gln	Ile	Phe	Gln	Leu	His	Thr	Thr	Leu	Ala	Glu	Thr	Pro	Ala	Gly	
						820				825							830
	Ser	Leu	Asp	Ala	Leu	Cys	Ser	Ala	Pro	Gly	Asn	Ala	Ala	Thr	Thr	Gln	
						835				840							845
25	Leu	Gly	Pro	Tyr	Ala	Phe	Lys	Ile	Pro	Leu	Ser	Ile	Arg	Gln	Lys	Ile	
						850				855							860
	Cys	Asn	Ser	Leu	Asp	Ala	Pro	Asn	Ser	Arg	Gly	Asn	Asp	Trp	Arg	Leu	
	865					870						875					880
	Leu	Ala	Gln	Lys	Leu	Ser	Met	Asp	Arg	Tyr	Leu	Asn	Tyr	Phe	Ala	Thr	
30						885					890						895
	Lys	Ala	Ser	Pro	Thr	Gly	Val	Ile	Leu	Asp	Leu	Trp	Glu	Ala	Arg	Gln	
						900				905							910
	Gln	Asp	Asp	Gly	Asp	Leu	Asn	Ser	Leu	Ala	Ser	Ala	Leu	Glu	Glu	Met	
						915				920							925
35	Gly	Lys	Ser	Glu	Met	Leu	Val	Ala	Met	Thr	Thr	Asp	Gly	Asp	Cys		
						930				935							940

(2) INFORMATION FOR SEQ ID NO:8:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 102 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS: not relevant
(D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: peptide

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:8:

	Asp	Glu	Glu	Thr	Leu	Asn	Thr	Pro	Cys	Tyr	Xaa	Gln	Leu	Glu	Pro	Arg
	1				5					10					15	
	Ala	Cys	Xaa	Ile	Leu	Leu	Asp	Gln	Leu	Gly	Thr	Tyr	Val	Phe	Thr	Gly
				20				25						30		
5	Glu	Ser	Tyr	Ser	Arg	Ser	Ala	Val	Lys	Arg	Leu	Gln	Leu	Ala	Val	Phe
			35				40						45			
	Ala	Pro	Ala	Leu	Cys	Thr	Ser	Leu	Glu	Tyr	Ser	Leu	Arg	Val	Tyr	Cys
		50					55					60				
	Leu	Glu	Asp	Thr	Pro	Val	Ala	Leu	Lys	Glu	Val	Leu	Glu	Leu	Glu	Arg
10	65				70					75					80	
	Thr	Leu	Gly	Gly	Tyr	Leu	Val	Glu	Glu	Pro	Lys	Pro	Leu	Met	Phe	Lys
				85						90					95	
	Asp	Ser	Tyr	His	Asn	Leu										
15							100									

WHAT IS CLAIMED IS:

1. An isolated vertebrate UNC-5 protein comprising SEQ ID NO: 5, 6, 7 or, 8, or a fragment thereof having vertebrate UNC-5-specific activity.

2. An isolated protein according to claim 1, wherein said protein specifically binds a natural netrin protein.

3. A recombinant nucleic acid encoding a protein according to claim 1.

4. A cell comprising a nucleic acid according to claim 3.

5. A method of making an isolated vertebrate UNC-5 protein, comprising steps: introducing a nucleic acid according to claim 3 into a host cell or cellular extract, incubating said host cell or extract under conditions whereby said nucleic acid is expressed as a transcript and said transcript is expressed as a translation product comprising said protein, and isolating said translation product.

6. An isolated vertebrate UNC-5 protein made by the method of claim 5.

7. An isolated vertebrate *unc-5* nucleic acid comprising SEQ ID NO: 1, 2, 3, or 4, or a fragment thereof having at least 24 consecutive bases of SEQ ID NO: 1, 2, 3, or 4 and sufficient to specifically hybridize with a nucleic acid having the sequence of the corresponding SEQ ID NO: 1, 2, 3, or 4 in the presence of natural *C. elegans unc-5* cDNA.

8. A method of screening for an agent which modulates the binding of a vertebrate UNC-5 protein to a binding target, said method comprising the steps of:

incubating a mixture comprising:

an isolated protein according to claim 1,

a binding target of said protein, and

a candidate agent;

under conditions whereby, but for the presence of said agent, said protein specifically binds said binding target at a reference affinity;

detecting the binding affinity of said protein to said binding target to determine an agent-biased affinity,

wherein a difference between the agent-biased affinity and the reference affinity indicates that said agent modulates the binding of said protein to said binding target.

- 5 9. A method according to claim 8, wherein said binding target is a natural netrin protein.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US98/03143

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : C07K 1/00, 14/00, 17/00; C07H 21/02, 21/04; G01N 33/53

US CL : 530/350; 536/23.1; 435/7.1

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 530/350; 536/23.1; 435/7.1

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

DIALOG: DATABASES WPI, MEDLINE, USPATFUL. AUTHOR AND WORD. SEARCH TERMS INCLUDE UNC-5 AND VERTEBRATE.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Database Medline on Dialog, US National Library fo Medicine, (Bethesda, MD, USA), No. 08202090 95037661, CULOTTI JG. 'Axon Guidance mechanisms in Caenorhabditis elegans,' Current opinion in Genetics and Development, abstract, August 1994, Vol. 4, No. 4, pages 587-595, see entire document.	1-9



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:	
A document defining the general state of the art which is not considered to be of particular relevance	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
B earlier document published on or after the international filing date	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
O document referring to an oral disclosure, use, exhibition or other means	*Z* document member of the same patent family
P document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

06 APRIL 1998

Date of mailing of the international search report

09 JUN 1998

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231

Facsimile No. (703) 305-3230

Authorized officer

HEATHER BAKALYAR

Telephone No. (703) 308-0196